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Urban Soundscapes of the World: selection and reproduction of urban acoustic environments with soundscape in mind

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ABSTRACT

The advent of realistic yet affordable immersive audio-visual recording and reproduction systems that combine binaural or spatial audio with 360-degree video, backed by increasingly efficient and realistic acoustic simulation and auralization models, has led to an increased interest in the acoustic design of urban environments. Architects and designers are however well-known to work by example. One of the goals of the Urban Soundscapes of the World project is therefore to compile a comprehensive reference database of high quality immersive audio-visual recordings of urban sites, within a range of cities worldwide. The well-documented exemplars in this database can be used to serve as an ecologically valid baseline for assessing the perceptual influence of noise control and soundscaping measures through auralization. This paper reports on a perception-based protocol that was developed for the purpose of site selection, in particular for systematically identifying spots within a city with a specific soundscape. This protocol contains an online questionnaire that is conducted among panels of local experts, and that asks participants to pinpoint outdoor public spaces within the city that are perceived in specific ways, regarding the presence of sound sources, the core affect and emotion evoked, and the appropriateness of the sound environment. This approach was designed to lead to a range of urban sites with a wide variety of soundscapes, such that a good statistical power can be achieved in perception experiments that are conducted on the basis of the audio-visual recordings in the database.

Keywords: Soundscape, Audiovisual, Recording I-INCE Classification of Subjects Number(s): 66

1. INTRODUCTION

1.1 Reproduction of urban acoustic environments

The role of sound reaches far into society, affecting our living, working and recreation conditions. The presence of environmental sound impacts upon the ease of communication, as well as upon comfort and health. Not surprisingly, soundscape is an important factor in the perception of the quality of one's living environment. Ambient sounds evoke thoughts and emotions, may have associated meanings, and influence moods or steer behavior. The soundscape approach to the assessment of outdoor space explores the complex relationships between individuals, communities and the acoustic environment (1, 2). Placing the listener central, the elements of the acoustic environment are hereby not only described in terms of sound pressure levels, but also in terms of psychoacoustical properties, meaning, aesthetics and evoked emotions, within the context in which these acoustic environments are perceived.

Cities comprise of many types of outdoor spaces, each with their distinct soundscape. Inspired by the potential positive effects a fitting acoustic environment may have on well-being, the challenge of designing urban acoustic environments has attracted sporadic attention since long (3). However, it is only during the past decade that research interest in this field has risen considerably, partly driven by the advent of realistic and affordable immersive audio-visual reproduction systems, backed by

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increasingly efficient and realistic acoustic simulation and auralization models (4). Physics-based methods may soon make it possible to render indoor virtual acoustic scenes that cannot be distinguished from real auditory environments (5). Auralization techniques are therefore more and more applied in the design of acoustically demanding spaces, such as concert halls, auditoria or movie theatres.

Auralization of urban outdoor spaces differs from the auralization of indoor spaces mainly in the model scale (propagation distance, number of surfaces and other objects), and in the number and complexity of sound sources that have to be considered. These issues cannot easily be resolved through software optimization and/or an increase in computing power. Therefore, high-quality immersive recordings (spatial audio combined with 360° visual) of existing spaces are highly valuable to serve as an ecologically valid baseline, on the basis of which the perceptual influence of noise control and soundscaping measures can be assessed through auralization. Equipment for performing such combined audio-visual recordings and for immersive playback is rapidly becoming affordable. However, to date no common protocols or standards exist for the recording and playback process, and as a consequence, the availability of high-quality recordings is sparse.

More importantly, architects and designers commonly work by example. Creating a reference database of good (and bad) examples of urban acoustic environments with their well-described context, including the visual setting, would support the further introduction of urban soundscape design in education and practice.

1.2 The Urban Soundscapes of the World project

The *Urban Soundscapes of the World* project aims to set the scope for a standard on immersive recording and reproducing urban acoustic environments with soundscape in mind, and to create a database of documented exemplars in the process. Using a combined setup (binaural, ambisonics and 360° video), a series of immersive recordings of the acoustic and visual environment at a selection of locations in a range of cities worldwide will be collected. The project differs from earlier work, such as the "Urban Sounds" project performed in Parma (6, 7), in its scale, and in the systematic selection of recording locations. One of the basic ideas behind the project is that, within each city, *sites are selected in a systematic and perception-based way*, grounded in the experience of local experts: people familiar with the sounds that can be heard in that city. To achieve this objective, the project is supported by a community of local teams, i.e. a worldwide panel of soundscape researchers at various universities and institutions that are involved throughout the different stages of the project, and that facilitate the outreach to local experts. A systematic site selection protocol should then result in a wide range of urban sites with a variety of soundscapes. This paper reports on the perception-based protocol that was developed for the purpose of site selection. In Section 2, the site selection protocol is presented, and in Section 3, the initial results for the cities of Ghent (Belgium) and Montreal (Canada) are presented.

2. SITE SELECTION PROTOCOL

2.1 Sampling strategies for soundscapes and landscapes

Sampling of urban sites for performing soundscape evaluation studies on the basis of high-quality recordings of the acoustic environment is most often performed in an *ad hoc* manner. Outdoor public spaces are hereby selected top-down, typically using purposive or convenience sampling, based on their value for residents, visitors or tourists, the presence of (a combination of) particular sound sources, or on past or planned noise control or soundscape interventions at the site. Using such a sampling method, the occurrence of a selection bias is very likely, as sites will be selected that are supportive for the study at hand. When a representative coverage of city soundscapes is the aim, for example for preservation or education, a more systematic, probability-based site selection strategy might be more favorable.

During the second half of the 20th century, a rise in the importance of aesthetics in environmental management has led to the development of a plentitude of selection and quality assessment methodologies for the preservation of rural and urban landscapes (8, 9, 10). It thus seems natural to draw inspiration from the landscape field. Systematic site selection methods for landscape study, conservation and planning are often based on objective factors such as land cover (11), as well as perception, visual preference and emotional attachment of local residents with the landscape (12, 13). The latter are typically evaluated through surveys or interviews, in order to select a sample of sites covering an as heterogeneous as possible set of landscapes (14).

2.2 Perception based site selection

Based on the above, a bottom-up community-driven approach for site selection is followed in the present work, based on the perceptual properties of the soundscape. The underlying dimensions of soundscape perception have been studied extensively over the past years. Two independent emotional dimensions of soundscape perception often arise when a principal component analysis is performed on verbal soundscape descriptors. These components can be labelled "pleasantness" and "eventfulness", see e.g. (15), or "calmness" and "vibrancy", see e.g. (16), both very well matching the valence and arousal axes in the core affect model of Russell (17).

In order to achieve a stratified sampling over this perceptual space of soundscapes, an online survey was constructed. In the initial version of the survey described in this paper, the goal was to obtain locations within the city that more or less uniformly cover each of the four quadrants of the 2D perceptual space. Figure 1 shows the labels that were used in the survey to describe each quadrant; these are based on the verbal analysis reported in (15). It was decided to use two labels in each quadrant, one more closely related to the pleasantness axis and one more closely related to the eventfulness axis, because there are no suitable labels directly at 45°, 135°, 225° and 315°.

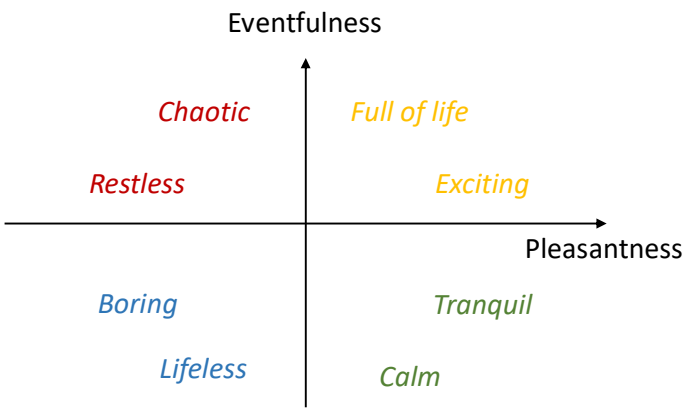


Figure 1 – Soundscape attributes along the pleasantness and eventfulness dimensions.

For each set of two labels X and Y, participants were asked to pinpoint the best matching public open space on a map of their city Z, using the following question: "Considering public open spaces (squares, parks, traffic-free streets etc.) within the city center of Z, where do you experience the soundscape to be the most X and Y during the day? Please drag the marker on the map to that location." Figure 2 shows a screenshot of this question (applied to the city of Montreal), which is repeated for all four combinations of labels. The selected longitude and latitude are then saved for subsequent spatial clustering analysis (see Section 3). Finally, only basic demographic information is gathered (mainly age and gender), keeping the survey short in order to reach as many participants as possible.

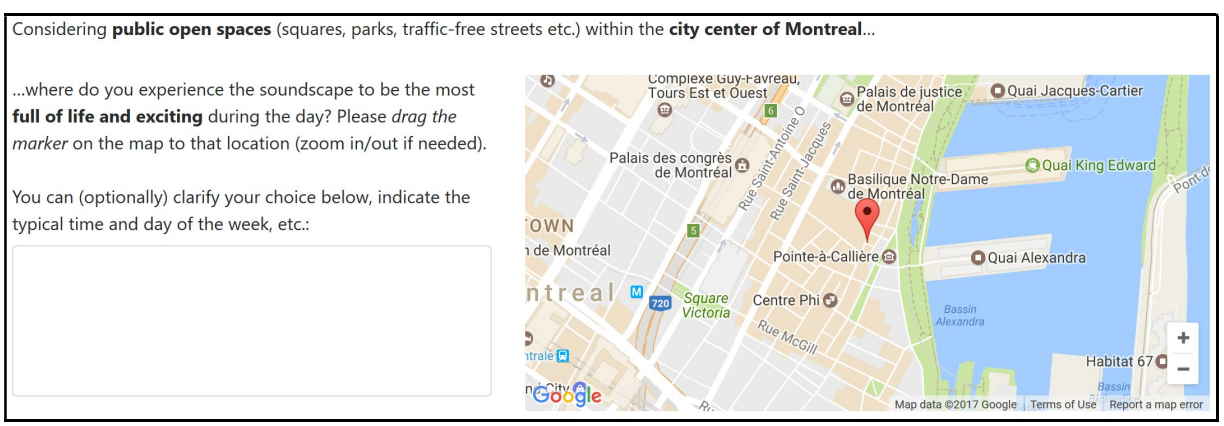


Figure 2 – Snippet of the online site selection survey for the city of Montreal.

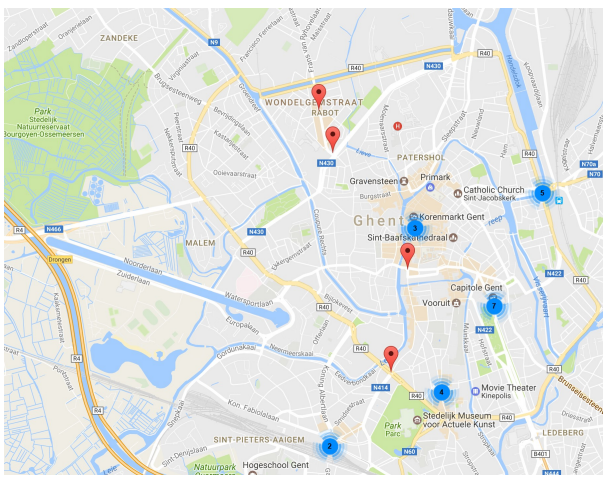
3. RESULTS

3.1 Ghent, Belgium

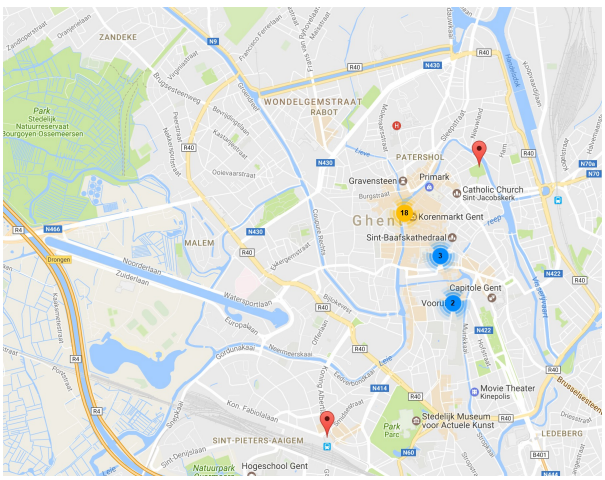
The survey for the city of Ghent (http://urban-soundscapes.org/sites/survey.php?city=ghent) was deployed as the initial test case. A call for participation was distributed among graduate students in engineering and psychology at Ghent University, and was posted on a Facebook page of the city of Ghent. Over a period of 10 days, 27 people participated in the survey (18 male, 8 female, 1 gender not specified; average age 30.3 ± 11.2 yr).

Figure 3 shows the selected sites for each of the four combinations of labels, clustered using the Google MapClusterer API. Note that the total number of selected locations can be smaller than the number of participants, as locations very close to the initial location of the marker were automatically excluded, assuming that in that case the participant did not answer the question by moving the marker.

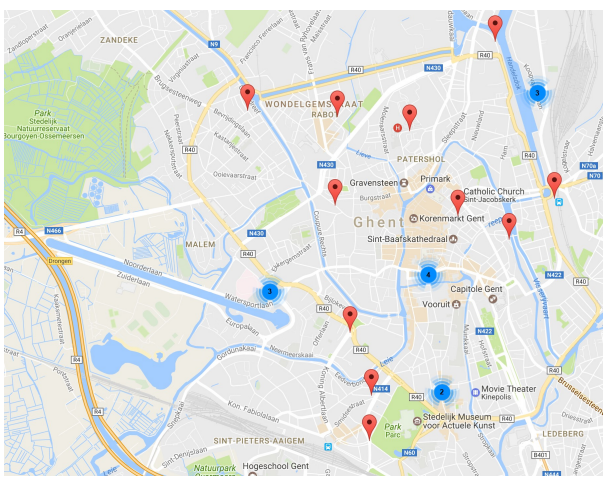
(a) chaotic and restless



(b) full of life and exciting



(c) lifeless and boring



(d) calm and tranquil

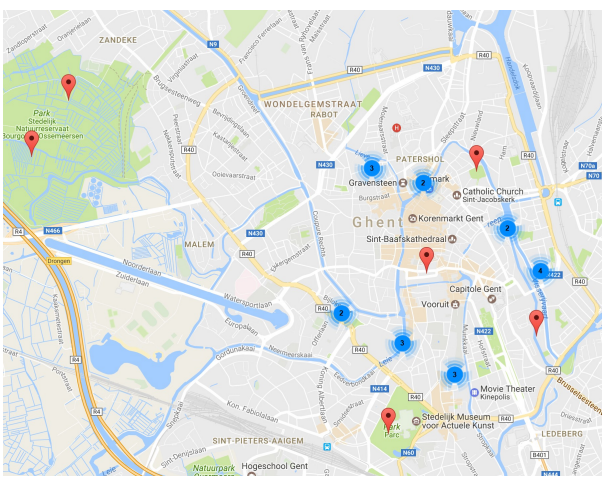


Figure 3 – Clustered locations for the city of Ghent.

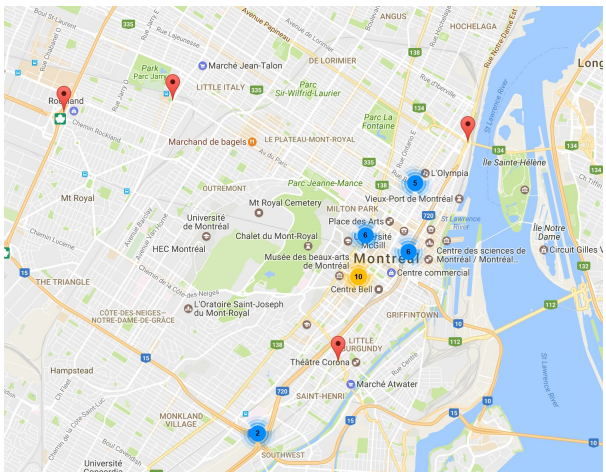
The locations having a soundscape "full of life and exciting" show the largest agreement among participants (31% of participants selected the *Graslei* neighborhood, 31% the *Korenmarkt* neighborhood, and 12% the *Emile Braunplein* neighborhood), followed by those "chaotic and restless" (*Zuid*: 27%, *Dampoort*: 23%, *Overpoort*: 15%) and "calm and tranquil" (*Visserij*: 23%, *Prinsenhof*: 12%, *Bijloke*: 12%). Locations denoted as having a "lifeless and boring" soundscape are most spread out (*Kouter*: 15%, *Watersportbaan*: 12%, *Handelsdok*: 12%); furthermore, a number of participants mentioned that these locations were the hardest to select.

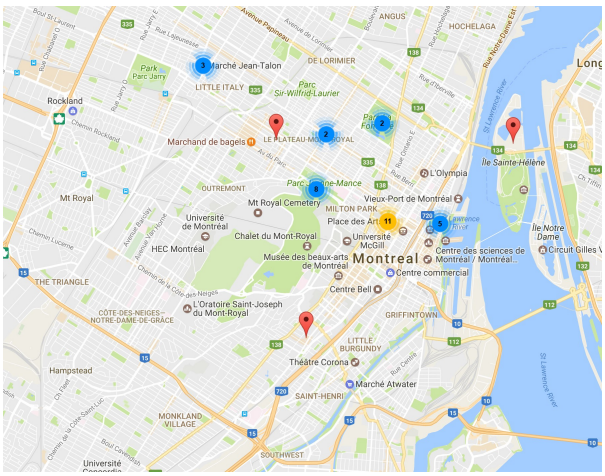
3.2 Montreal, Canada

A call for participation for the survey for the city of Montreal was distributed among graduate students in audiology at the Université de Montréal, announced among the Sounds in the City project members at McGill University, posted on the surround sound and BRAMS mailing lists, circulated among APGT Montreal (professional association of Montreal tourist guides), and posted on the Facebook page Montreal – Then and Now. Over a period of 7 days, 36 people participated in the survey (18 male, 17 female, 1 gender not specified; average age 38.9 ± 12.9 yr). Figure 4 shows the selected sites for each of the four combinations of labels for the city of Montreal.

(a) chaotic and restless

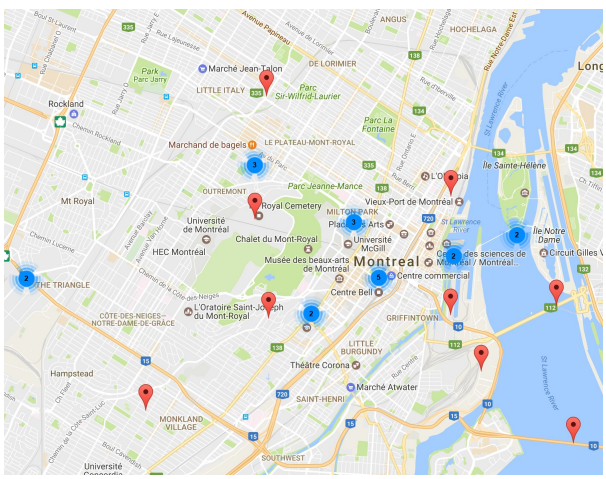
(b) full of life and exciting





(c) lifeless and boring

(d) calm and tranquil



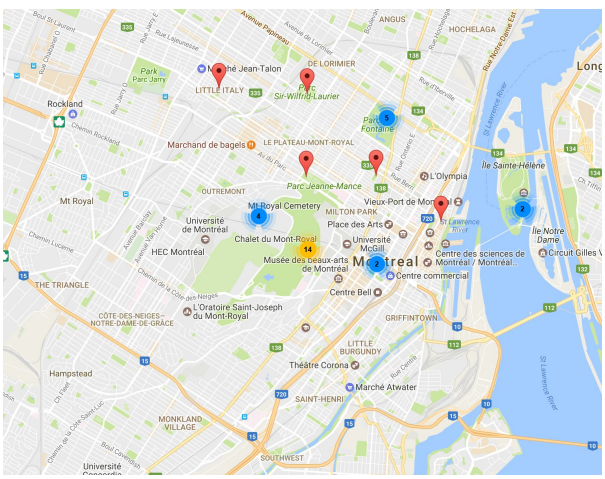


Figure 4 – Clustered locations for the city of Montreal.

As with the results for Ghent, a similar pattern emerges. The locations having a soundscape "full of life and exciting" (*Place des arts*: 17%, *Monument à Sir George-Étienne Cartier*: 17%, *Square Phillips*: 11%), "chaotic and restless" (*Rue Sainte Catherine*: 28%, *Place Émilie-Gamelin*: 14%, *Palais des congrès neighborhood*: 11%) and "calm and tranquil" (*Mont Royal park*: 39%, *Parc La Fontaine*: 14%, *Mont Royal Cenetary*: 11%) show the largest agreement among participants. Again, locations denoted as having a "lifeless and boring" soundscape are most spread out, no clear location reaches more than 10% of the votes.

4. DISCUSSION

Although the number of participants is relatively low, the results for both surveys among local experts in Ghent and Montreal consistently suggest that the four quadrants in the 2D core affect model for soundscape perception are not equally represented among urban locations. Obviously, not all

locations in a city are visited with the purpose of experiencing the soundscape. Moreover, the acoustic environment in many urban locations does not necessarily attract attention if sound is not the purpose of being there, and the soundscape at these locations is therefore not always memorable. Such locations can be labeled “lifeless and boring”, and this would explain why little convergence can be achieved for this category, as compared to the other three categories. Therefore, a hierarchical representation might be more suitable to categorize urban locations with regards to how the soundscape at these locations is typically perceived. Figure 5 shows such a possible representation.

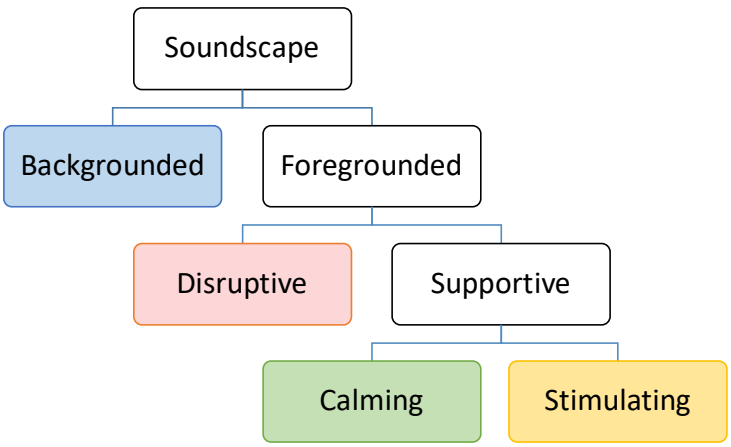


Figure 5 – Hierarchical classification of urban locations according to how the soundscape is perceived.

In the first stage, locations are classified according to the influence of the acoustic environment on the perception of the total environment. The scale varies from no influence (i.e. the soundscape is “backgrounded”) to a strong influence (i.e. the soundscape is “foregrounded”), as the sound at the location increasingly leads to awareness of the acoustical environment. This is not a crisp distinction, one could mathematically formalize this classification using fuzzy set membership. The hypothesis is that locations at which people are more aware of the soundscape will be remembered more easily. In the second stage, locations are scaled according to how well the soundscape matches expectations. These expectations can be both place-related (e.g. how well the landscape is congruent with the soundscape, how well sources are visible etc.) and person-related (e.g. how much the soundscape interferes with the goals and activities of the listener). The scale ranges from disruptive to supportive, and relates to the pleasantness axis in the 2D core affect model, however, taking into account person and place. In the third stage, locations are scaled according to how they arouse the listener. The scale ranges from calming to stimulating, and relates to the eventfulness axis in the 2D core affect model.

5. CONCLUSIONS AND PERSPECTIVES

In this paper a perception-based protocol for systematically identifying spots within a city with a specific soundscape is presented. This protocol consists of an online questionnaire that is conducted among local experts, and which asks participants to pinpoint outdoor public spaces within the city that are perceived differently along the soundscape perception dimensions of pleasantness and eventfulness. The results of this site selection for two cities, Ghent and Montreal, are presented, and it is shown that the approach leads to a range of urban sites with a wide variety of soundscapes. However, the results suggest that the categories in the 2D core affect based model are not equally represented among urban locations. To better reflect the influence of the purpose why particular places are visited, and how the soundscape interacts with the goals and expectations of the listener, a hierarchical classification scheme is presented.

This work is conducted within the framework of the Urban Soundscapes of the World project, in which one of the goals is to create a database of high-quality audio-visual recordings at selected sites within a number of cities worldwide. Combined and simultaneous audio and video recording will therefore be performed in the coming months at the selected locations using a portable recording setup consisting of the following components: binaural audio (HEAD acoustics HSU III.2 and SQobold), first-order ambisonics (Core Sound TetraMic with Tascam DR-680 MkII) and 360-degree video (GoPro Omni). This setup ensures high-quality capture and allows for subsequent playback on a range

of systems (headphones or multi-channel loudspeaker systems for audio, screen or VR headsets for video). The database of immersive recordings will be made available to the scientific community, together with relevant contextual material related to each site, such as GIS data and typical use, to foster collaboration and exchange, and to support research on audio-visual interaction in perception and quality assessment of urban outdoor environments.

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